EXECUTIVE SUMMARY

INTRODUCTION

The studies reported here were completed in support of Objective 4.2 of the San Juan River Basin Recovery Implementation Plan (SJRIP) long range plan to "Identify, Protect, and Restore Habitats" for the endangered Colorado pikeminnow and razorback sucker. Field work was completed between 1992 and 1998. These studies also form a portion of the foundation for flow recommendations for the San Juan River in New Mexico, Colorado and Utah, a major milestone of the SJRIP long range plan.

The portion of the San Juan River addressed by these studies lies between Navajo Dam (River Mile (RM) 224) and the inflow to Lake Powell (RM 0). Hydrology, geomorphology and aquatic habitat were assessed.

HYDROLOGY

Prior to control by Navajo Dam in 1962, the San Juan River was relatively unregulated, although substantial diversion of water for irrigation and other uses has taken place since about 1870. The hydrology from 1929 to 1962 was relatively natural in shape, although depleted in volume, particularly in the summer. The river was characteristic of other large southwestern U.S. rivers, exhibiting a large spring runoff, associated with low base flow. Late summer and fall flows were strongly influenced by runoff associated with high intensity, short duration storm events from poorly vegetated lower river drainage basins, causing large increases in flow and sediment for short periods of time.

Subsequent to 1962, the hydrograph of the San Juan River was drastically changed as a result of conservation and flood control operation of Navajo dam. The dam was operated with the objective to conserve water and stabilize downstream flow, resulting in reduced spring discharge and elevated summer, fall and winter flow.

The test flow period clearly demonstrated the ability to operate Navajo dam in a manner that would mimic a natural hydrograph and ameliorate some of the impact of the dam on hydrology. This is especially true for the present level of depletions, but applies for additional levels of depletion as well. Much of the pre-dam hydrograph can be restored in terms of general shape, although magnitude is somewhat reduced. The test flows better matched pre-dam spring flows than winter base flows. A minimum release of 500 cfs from Navajo dam kept the winter flows elevated above pre-dam conditions.

While, on average, it appears that the potential exists for adequate mimicry, there are extreme conditions that cannot be met. With the present release capacity of Navajo Dam at 5,000 cfs, the ability to produce large spring floods below Farmington has been diminished. Further, historic minimum summer through winter base flows would likely not be matched, both as a result of restrictions on minimum releases and a desire to maintain more flow in the river to benefit the fish during these times.

Not only were flows impacted, but the temperature regime in the river was altered. The post-dam water temperatures in the summer at Shiprock are now cooler than pre-dam at Archuleta. With re-operation and increased releases during spring runoff, the depressed temperatures will extend further down river. The net result is a further loss in range for temperature critical activities of over 140 km. While the program has the goal of expanding range, the opportunity may be limited by temperature suppression. Further studies are needed to determine if this temperature suppression is limiting range in otherwise suitable habitat and the options available to correct it if it is found to be a problem.

Summer and autumn storm events markedly impact habitat quality in the San Juan by depositing fine sediment over cobble substrate and in backwaters. In the lower portion of the river, below Four Corners the storm influence is sufficient to require flushing flows to clean habitats 50% of the time on average. In the upper portions of the river below Farmington the frequency falls to about 1 year in 10 on average, suggesting that habitat is more easily maintained in the upper reaches of the river.

GEOMORPHOLOGY

History of Fluvial Morphology

The San Juan River has undergone a variety of changes over the last 100 years, for which we have documented evidence since the 1930's. The condition of the river in the 1930's is likely not the condition to which we would desire restoration. The lower portion of the river, including the canyon below Bluff, Utah, was heavily sediment laden. There was no stability to the channel and most of the cobble was probably buried in 0.3 to 2.0 meters of sand. By the early 1950's suspended sediment load dropped by nearly 50%, allowing the channel to scour the sand from the system and form a more defined channel and the invasion of tamarask had begun, with substantial establishment by this period. The smaller, stabler channel was quite different than the 1930's channel with larger, more stable islands and secondary channels. By the time Navajo dam was constructed in the early 1960's, the channel had stabilized even more, although the mean bankfull channel width was about the same as a decade earlier. With stabilization came a loss of channel complexity with fewer and smaller islands. Between the early 1960's and 1988, the channel became much smaller, but in the process, gained significant island area and island count. Since the bankfull channel area lost is almost equal to the island area gained, it appears that previous sand and cobble bars became vegetated during this period of reduced spring peak flows. The channel is much more stable and is now heavily armored with Russian Olive along most of its course. The loss of bankfull channel capacity, estimated at between 15% and 30%, now requires less flow for channel maintenance and out-of-bank conditions occur at reduced flows.

Geomorphological Reach Description

To assist interpretation of research results in such a long reach of river, eight geomorphological reaches were identified. Following is a brief description of each reach:

Reach 1 (RM 0 to 16, Lake Powell confluence to near Slickhorn Canyon) is a low gradient, sand-bottomed reach created by backwater from Lake Powell.

Reach 2 (RM 17 to 67, near Slickhorn Canyon to confluence with Chinle Creek) is canyon bound but is located above the influence of Lake Powell, with a higher gradient, dominated by riffle-type habitat.

Reach 3 (RM 68 to 105, Chinle Creek to Aneth, Utah) is characterized by higher sinuosity and lower gradient (second lowest) than the other reaches, a broad floodplain, multiple channels, high island count, and high percentage of sand substrate. Backwaters are more abundant, but are easily perturbated by summer storm flows.

Reach 4 (RM 107 to 130, Aneth, Utah, to below "the Mixer") is a transitional reach between the upper cobble-dominated reaches and the lower sand-dominated reaches with relatively low abundance of backwaters and little clean cobble.

Reach 5 (RM 131 to 154, the Mixer to just below Hogback Diversion) is predominantly multi-channeled. Backwaters and spawning bars in this reach are much less subject to perturbation during summer and fall storm events than the lower reaches.

Reach 6 (RM 155 to 180, below Hogback Diversion to confluence with the Animas River) is predominately a single channel. Cobble and gravel substrates dominate, and cobble bars with clean interstitial space are more abundant in this reach than in any other. Four diversion dams limit upstream movement of fish.

Reach 7 (RM 181 to 213, Animas River confluence to between Blanco and Archuleta, New Mexico) is similar to Reach 6 in terms of channel morphology. The river channel is very stable, consisting primarily of embedded cobble substrate as a result of controlled releases from Navajo Dam and much of the river bank has been stabilized and/or diked.

Reach 8 (RM 213 to 224, between Blanco and Archuleta and Navajo Dam) is the most directly influenced by Navajo Dam, which is situated at its uppermost end (RM 224). This reach is predominantly a single channel with cobble substrate and clean, cold water as a result of Navajo Dam. These cool, clear water conditions have allowed development of an intensively managed blue-ribbon trout fishery to the exclusion of the native species in the uppermost portion of the reach.

Table of Contents

Channel Geometry

During the course of the seven-year research study, the channel has shown a general trend of scour, resulting in an increase of mean cross-sectional area of 7 - 10%. The scour was most pronounced in the earlier years, with a trend towards a stability. This short term change is well within the range of changes seen at USGS gages over the last 50 years. The increased scour was accompanied by an increase in the portion of cobble substrate as a result of removing sand from the system.

Continued channel scour can lead to channel simplification if the main channel degrades and secondary channels are isolated. Studying the trend in island count at low flow over the research period indicated a slight trend to simplification when peak flows were near bankfull or less. Channel complexity increased when flows exceeded 10,000 cfs for more than 5 days.

The scour that has occurred has resulted in an increase in bankfull channel capacity of about 12% over the research period to an average flow of about 8,000 cfs. Since the bankfull channel area is still much less than during pre-dam conditions, the historic bankfull capacity was likely greater than 8,000 cfs, although now measurements have been made to quantify the historic bankfull discharge.

Cobble Bar Characterization

Characterization of cobble bars in the San Juan River indicates that there are multiple locations that have characteristics suggesting that they are suitable for spawning as well. Cobble with substantial depth of clean open interstitial space is more abundant above RM 131 than below, corresponding to the other studies that indicate an increase in sand substrate with distance down river.

Flows to Support Cobble Transport

Based on the results of the studies conducted to date, it is concluded that sufficient local cobble movement exists to provide some clean cobble for spawning with flows of 2,500 cfs or higher for a duration of at least 10 days prior to spawning.

The bankfull flow of 8,000 cfs was selected as the flow required for cobble transport and bar building based on model results of four research reaches and flow calculations at the RT cross-sections. Examination of the cobble movement data suggests an 8-day duration as appropriate for the minimum duration necessary for bar-building cobble transport. An average recurrence frequency of 1 year in 3 years (33%) will provide the frequency of conditions necessary for maintenance of channel capacity. Therefore, 8,000 cfs for 8 days with an average recurrence frequency of 1 year in 3 years are the conditions recommended for cobble bar construction and channel maintenance. From a sediment-transport and channel-maintenance standpoint, the full range of flows from 2,500 cfs through 10,000 cfs plays an important role. Mimicking a natural hydrograph that includes flows in this range is necessary. Just providing the conditions required at 8,000 cfs would be inadequate and could lead to channel simplification and armoring over time. Because of the short period of study, monitoring should continue to verify these relationships.

previous next

return to Main Menu

Flows above 10,000 cfs are recommended periodically for maintaining channel complexity and floodplain integrity. The response of islands to flows indicates that flows less than 10,000 cfs (1992 to 1994) may result in channel simplification with time unless combined with higher flows that develop new secondary channels and islands through overbank flow (1995). High flows are the most-altered portion of the natural hydrograph in the San Juan River. Historically, these flows have played a major role in floodplain development. While all the mechanisms of importance have not been identified and quantified during the research period, the general paradigm of natural flow mimicry would not be met without restoration of these higher flows to some degree. Therefore, a conservative threshold requirement of 5 days at or above 10,000 cfs is recommended for purposes of natural flow mimicry and maintenance of channel complexity.

The cobble bar maintenance flow (2,500 cfs) should occur at a frequency sufficient to ensure long-term reproductive success of the species of interest. The cobble bar construction flow (8,000 cfs) is needed less frequently if bars are maintained (cleaned and reworked) on a regular interval. Data suggest that the bars can be reworked to provide clean cobble for several years without the necessity of reconstruction or replacement. Channel maintenance requirements indicate an average recurrence of 1 year in 3 years for flows above 8,000 cfs. The 10,000-cfs flow condition is not required as frequently. Historically, it had been 8 years between the occurrence of these conditions (1987 and 1995). Looking at the potential for channel complexity deterioration indicated in Figure 3.29, the required average recurrence frequency for maintenance of channel complexity and floodplain integrity was determined to be 5 years. During the pre-dam period, the 10,000-cfs flow conditions were met 39% of the time (4 years in 10, vs. 2 years in 10 in this recommendation). The reduction in channel capacity that has occurred since the closure of Navajo Dam allows a lower frequency of achieving these conditions. Given the short duration of the studies upon which these recommendations are based, future refinement of the recommendations will likely be necessary, thus requiring an adaptive management approach.

LOW VELOCITY HABITAT MAINTENANCE

During the course of the research period, no relationship could be found between spring runoff conditions and bedform structural change influencing backwater formation. Studies of bar change did not indicate a relationship between bar height and peak runoff magnitude or volume for the range of flows tested, likely because most peak flows were at or above bankfull where stage and shear stress change little with change in flow. Further, a large percentage of backwaters are associated with secondary channel or tributary mouths. Therefore, the structural studies concentrated on backwater cleaning processes.

Detailed monitoring and modeling of fine sediment transport in two secondary channel associated backwaters indicated flows must be in the 4,000 - 5,000 cfs range to initiate cleaning. Further, flushing is improved by longer durations and higher magnitudes of spring flows. Both backwaters begin to refill with sediment on the descending limb of the hydrograph. Modeling indicated that steeper descending limbs tended to limit the amount of deposition. Summer storm events can fill in these backwaters during heavily perturbating (multiple sediment laden storm events in one season) years. Modeling is very sensitive to sediment concentration and grain size distribution, making it difficult to accurately predict performance in a non-calibration year. So far, each year analyzed has required a separate calibration, with low accuracy of predicted capability. For modeling to be effective, more intense sediment concentration data would be needed in conjunction with a more robust model that would address the geometry of the bedform and the mechanisms of transport more precisely than the one dimensional model used.

Combining the results of the backwater cleaning measurements and modeling with the results of overall scour in the cross-sections, a threshold flow of 5,000 cfs has been identified as necessary for backwater cleaning, with a duration of 21 days and an average frequency of 50%.

SUSPENDED SEDIMENT ANALYSIS

In any study of fluvial morphology it is desirable to be able to measure sediment inflow and outflow to determine the sediment balance. While this is possible for non-storm influenced periods in the San Juan, it is not practical to measure all the inflows required in the San Juan River due to the numerous inflows. The sediment data collected did indicate that the concentrations measured fall within the range of historic sampling, although averages were on the low side of the historic mean This could represent a shift to lower sediment concentrations, or indicate a sampling bias as the non-runoff period was not sampled.

Sufficient analyses have been completed to know that the system is heavily perturbated by summer and fall storm runoff events, where measured tributary inflow concentrations of total suspended solids (tss) have been as great as 130,000 ppm (13%). These heavy sediment contributions lead to reduced backwater habitat quality and require more frequent flushing to maintain system health.

HABITAT

The quantity and quality of aquatic habitat in the San Juan River was determined in a number of different investigations. The surface areas of a wide variety of habitat types in the San Juan River were mapped thirteen separate times with flows ranging from 525 to 8,000 cfs. At times, the mapping occurred over the entire 225 miles of river from Navajo Dam to the confluence with Lake Powell. Some habitat types (runs, eddies, inundated vegetation and shoal) displayed strong relationships with mapping flows while other habitats (slackwaters) displayed high variability with no relationship to flow. Backwater habitats, although variable, demonstrated a systematic pattern related to the inundation of the mouths of secondary channels and the subsequent loss via flow through these channels at higher flows. Backwater habitat areas were also found to be diminished due to summer silt-laden storm events.

The habitats mapped through airborne videography and field studies were determined by visual inspection of surface features (eddy lines, riffle lines, etc. In order to verify that these habitats are physically different, an investigation was undertaken to quantify the physical conditions of these habitats. During this study it was found that the eight habitat types selected, significantly differed in most cases with respect to mean velocity, depth, and depth to embedded layer (DTE). Substrate composition also differed between some habitats with generally finer substrates being more abundant in lower velocity types and coarser substrates in higher velocity types. DTE tended to be higher in most habitats in the most upstream reach below Navajo Dam, indicating less embedded substrate in those areas. Highly reduced sediment loads in the upper reach was a likely explanation for that finding.

Storms were observed to increase the percentage of fines and/or decrease the DTE in every habitat described. Conversely, the cleansing action of high runoff was noted in nearly all habitats as well. This illustrated the necessity for considering the effect of hydrology on these particular attributes when describing specific habitats. For example, using DTE as a measure to distinguish between riffles and other relatively high velocity habitats following a large storm event might be counter-productive as riffle habitats would likely be similarly, highly embedded.

Because riffle and run habitat types were found to be physically different, they were sampled for abiotic and biotic parameters before and after spring runoff for the years 1994, 1995 and 1996 with the purpose of quantifying primary and secondary trophic structures. The physical parameters (depth to embedded layer, D_{50}, and percent surface area embedded) were significantly different between riffles and runs. Biological parameters (periphyton, detritus and invertebrates) were not different between habitat types. The comparison of sample locations (geomorphological reach) by habitat types for the abiotic and biotic parameters indicated significant longitudinal differences for periphyton, detritus and invertebrates with upper geomorphological reaches having higher densities (greater biomass) than lower reaches. The comparison between the lower 200 miles of the Colorado with the San Juan study area indicated similar characteristics in abiotic conditions and similar biomass levels for biological components.

Backwaters, which represented a critical habitat for native fishes were also quantified over a multiple year sequence. The results of this investigation indicated that storms reduced the biomass of phytoplankton, periphyton, and benthic invertebrates (chiefly chironomids) in San Juan River backwaters. In addition, periods of relative stability in discharge (i.e., reduction in frequency and/or intensity of storms) on the order of months during the fall-to-spring period resulted in increased production of phytoplankton, zooplankton, periphyton, benthic invertebrates, and detritus in San Juan River backwaters. However, storms also increased the abundance of zooplankton and detritus in some river reaches on certain occasions. Periphyton was the one parameter that displayed a clear longitudinal pattern following stable flows in the San Juan River, with biomass steadily declining downstream.

Backwater depth river-wide in the San Juan River was relatively high following the higher magnitude runoff in 1995, but declined to lower levels thereafter during a two-year period characterized by frequent storm events. The reductions in backwater depth in the San Juan River over the study period coincided with an increased amount of ultra-fine sized sediment accumulation in the backwaters. As a comparison, data from the Colorado River backwaters within the Moab to Potash reach tended to be deeper, less turbid, cooler, and more oxygenated than San Juan River backwaters over the same time period. Colorado River backwaters also contained higher levels of

Table of Contents

periphyton over the same time period as the San Juan River backwaters river-wide, while other biological parameters were similar on average.

During the monsoon period in 1997 when storms were prevalent, the San Juan, Colorado, and Green River backwaters contained similarly low primary and secondary productivity, indicating physical disturbances to the backwaters throughout all three drainages.

return to Main Menu

previous